Characterization and Mutagenicity of Smoke from Smoldering and Flaming Combustion of Peat and Red Oak Biomass Fuels

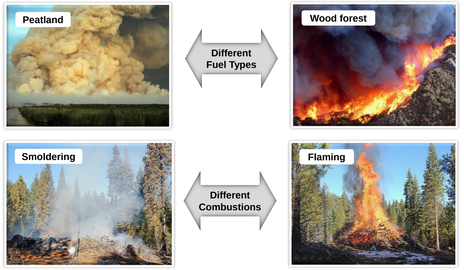
Yong Ho Kim[1], Sarah Warren[1], Todd Krantz[1], Charly King[1], Richard Jaskot[1], Michael Hays[2], Matthew Landis[3], Mark Higuchi[1], David DeMarini[1], M. Ian Gilmour[1]

[1]NHEERL, [2]NRMRL, and [3]NERL, U.S. Environmental Protection Agency, Research Triangle Park, NC, USA

Yong Ho Kim | kim.yongho@epa.gov | 919-541-2255

Background

Wildland fire smoke depending on fuel types and combustions



Health impacts of wildland fire smoke

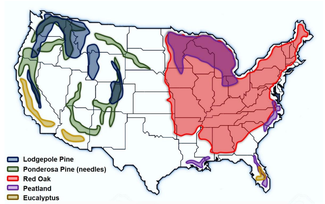
- Wildland fire smoke is a hazardous mixture of gaseous emissions and particulate matter (PM).
- It is not well understood if the health impacts of wildland fire smoke are influenced by fuel types or combustion conditions.

Research Hypothesis

- Toxicity of smoke emissions from wildfires varies depending on the type of fuel, combustion conditions, and resultant particle chemistry.

Materials & Methods

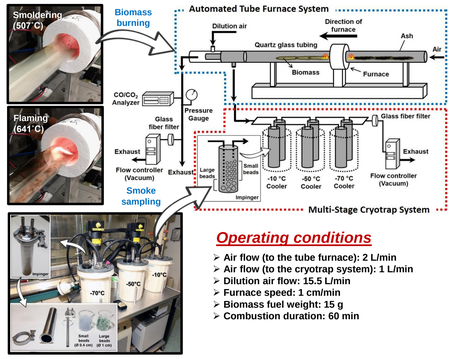
Tested biomass fuels and their distribution in the United States



- Red oak (obtained from the Air Pollution Prevention and Control Division at the US EPA)
- Peat (collected from the coastal plain of the eastern North Carolina, ARNWR)
- Ponderosa pine needles (provided by the Missoula Fire Sciences Laboratory)
- Lodgepole pine (provided by the Missoula Fire Sciences Laboratory)
- Eucalyptus (purchased from a local supplier)

Materials & Methods

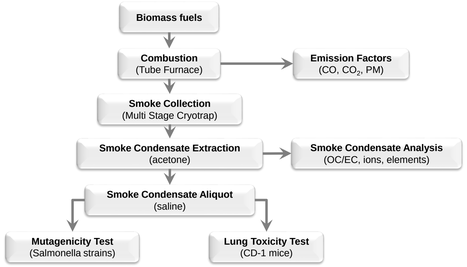
Biomass combustion and smoke sampling system



Operating conditions

- Air flow (to the tube furnace): 2 L/min
- Air flow (to the cryotrap system): 1 L/min
- Dilution air flow: 15.5 L/min
- Furnace speed: 1 cm/min
- Biomass fuel weight: 15 g
- Combustion duration: 60 min

Flow diagram of the biomass combustion study



Results

Characterization of Biomass Smoke

Table 1: Characteristics of biomass smoke emitted from the tube furnace system

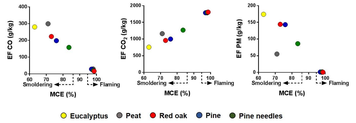
Fuel type		Red oak		Peat		Pine needles		Pine		Eucalyptus	
Combustion condition		Smoldering	Flaming	Smoldering	Flaming	Smoldering	Flaming	Smoldering	Flaming	Smoldering	Flaming
MCE (%)[1]		73±2	98.6±0.3	71±2	98±1	83±1	98±1	76±2	97±3	63±3	98±1
Conc.	CO (ppm)	793±104	68±16	1,385±468	122±51	602±117	119±34	766±85	165±137	1,201±184	128±74
	CO_2 (ppm)	2,167±385	4,867±352	3,425±1,292	4,750±261	3,067±664	6,967±1,490	2,458±415	6,808±2,272	2,058±231	6,667±916
	PM (mg/m³)	973	5	488	5	624	18	1,050	15	1,418	13
EF[2]	CO (g/kg fuel)	223	16	299	29	158	20	198	28	280	22
	CO_2 (g/kg fuel)	957	1,806	1,161	1,785	1,268	1,797	999	1,785	755	1,795
	PM (g/kg fuel)	144	0.6	55	0.6	86	1.6	143	1.3	174	1.1

[1] Modified combustion efficiency (MCE) = $\Delta CO_2 / (\Delta CO_2 + \Delta CO)$

[2] Emission factor (EF) r (g/kg) = (mass of carbon emitted as r x molecular weight r x 1000) / (molecular weight carbon x fuel carbon fraction x total mass of carbon)

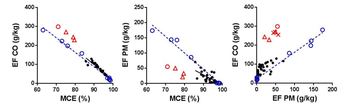
Results

Figure 1: Emission factors (EFs) of biomass smoke as a function of modified combustion efficiency (MCE)



- All EFs (except for the peat smoke from smoldering) were positively correlated with modified combustion efficiency (MCE).

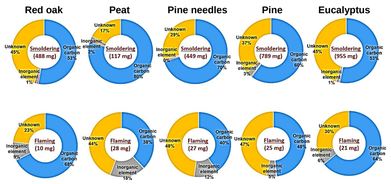
Figure 2: Comparison of emission factors (EFs) and modified combustion efficiency (MCE) with field measurements



- The combustion system presented is able to successfully simulate various field combustions.

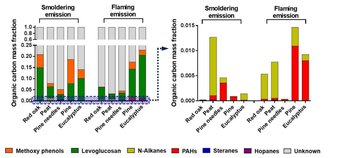
Characterization of Biomass Smoke Condensates

Figure 3: Chemical mass fraction of the biomass smoke condensates (BSC)



- BSC mass collected from smoldering was up to 47 times higher than that from flaming combustion.
- Organic carbon mass in the smoldering BSC was up to 39 times higher than that in the flaming BSC.

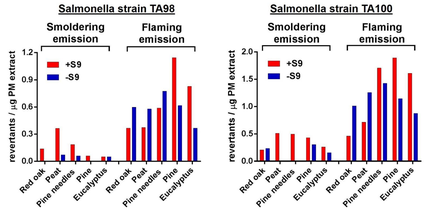
Figure 4: Organic carbon mass fraction of the biomass smoke condensates (BSC)



Results

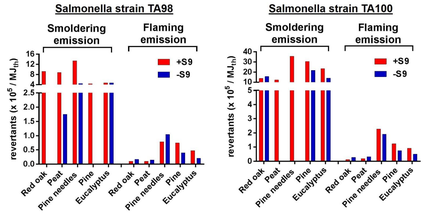
Mutagenicity of Biomass Smoke Condensates

Figure 5: Mutagenicity of the biomass smoke condensates based on Equal Mass



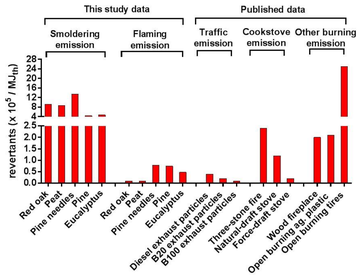
- Flaming emissions were more mutagenic on an equal mass basis.

Figure 6: Mutagenicity of the biomass smoke condensates based on Emission Factor



- Smoldering emissions were more mutagenic on an emission factor basis.

Figure 7: Comparison of mutagenicity emission factors from various combustions

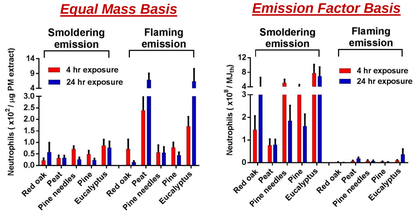


- The mutagenicity emission factors for smoldering emissions were ~20 times and ~4 times greater than those from diesel engine and inefficient open-burning sources (e.g., three-stone fire or wood fireplaces), respectively.

Results

Lung Toxicity of Biomass Smoke Condensates

Figure 8: Lung toxicity of the biomass smoke condensates



- Flaming emissions were more toxic in the lung on an equal mass basis while smoldering emissions could be more toxic on an emission factor basis.

Conclusions

- Type of fuel and combustion conditions have dramatic differences in emission characteristics, mutagenicity, and lung toxicity.
- The combustion and sample-collection system presented has great utility for characterization of simulated wildfire emissions.
- The system presented can be employed for health risk assessment from inhalation exposure to wildfire smoke.
- Health impacts of wildfire smoke can be assessed on an equal-mass fuel consumption basis or equal-mass PM exposure basis.

Future Work

Subchronic inhalation exposure study